of the observatory enclosure there is no measurable lateral deflection of the projectile while in flight. Truly round holes are always left by the rotating projectiles. Very striking results were obtained in an experiment made in Virginia in the presence of a number of Ordnance Officers. Two successive shots were fired at a target in one of which the projectile was made to rotate by means of the included charge and in the other of which the projectile was fired by powder outside of itself. In the one an excellent hit was made, leaving a true round hole, while in the other it happened that in the tumbling of the shell in the air it reached the target exactly broadside. The officers were naturally much impressed by this striking exhibit.

As in most of the investigations we undertake, the same general idea had long before occurred to others. Patents for somewhat similar devices were granted as long ago as the Civil War. So far as I am aware, however, no one hitherto has attained so good a measure of success in applying the turbine principle to projectiles.

MEANS OF MEASURING THE SPEED OF PROJECTILES IN FLIGHT

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In the course of the experiments on rotating projectiles from smooth bore guns I desired to measure the speed of flight in some instances, and as I lacked the usual chronographic apparatus employed by artillerists the following substitute occurred to me and proved very satisfactory after a few trials.

The projectile was fired obliquely across a horizontal beam of light reflected into the observatory from the siderostat. The solar beam was entirely cut off by a diaphragm at the wall of the observatory, except as it passed through two round holes about 6 inches apart. The shot was fired through the left hand one of these holes. About 2 meters inside of the observatory another smaller diaphragm with a small aperture in it was placed opposite to the second or right hand hole. The direction of the gun was so arranged that the shot passed through the hole in this second diaphragm also. About a meter beyond the second diaphragm was placed a double tinfoil screen, the two tinfoils being separated by a sheet of cardboard and connected by wires respectively to a circuit con-

taining an electromagnet which operated a shutter for the purpose which I am about to describe. Opaque cards were placed to cover the left hand hole in the first diaphragm through which the shot was fired and to cover the hole in the second diaphragm through which the shot passed after having accomplished two meters more of its flight. The passage of the shot through the tinfoils beyond closed the electric circuit and operated the shutter which has been mentioned.

The beam from the left hand hole of the first diaphragm passed to a mirror at 45° which reflected it at right angles upon a photographic plate caused to rotate in its own plane by means of an electric motor. The beam from the right hand hole of the first diaphragm, after passing through the second diaphragm was also reflected by the same mirror upon the same photographic plate but diametrically opposite to the first beam with respect to the center about which the plate rotated in its own plane. Between the mirror and the photographic plate was a long slit which restricted the two beams of light to mere streaks extending respectively from the center to the right hand and to the left hand of the photographic plate. Just above the long slit was placed the shutter controlled by the electromagnet.

It will readily be seen that when the gun was fired, first a beam from the left hand hole in the first diaphragm passed to the mirror and was reflected upon the rotating plate. After the projectile had covered the two meters leading to the second diaphragm, the other hole was opened and the second beam began to print upon the other half of the photographic plate. Immediately thereafter the electric circuit was closed, the shutter consequently closed, and so the photographic action stopped before the plate had made a half revolution. The delay in the electric action had no influence on the work provided the shutter closed before the plate made a half rotation. After development the blackened parts of the photographic plate were found to indicate a certain angle through which it had rotated between the time when the projectile opened the first aperture and the time when it opened the second aperture. Having determined the speed of the photographic plate by measuring the speed of the electric motor, the velocity of the projectile became known.

It is easy by this means to determine with some accuracy very great velocities of translation within a very short path. Even one meter path would be quite sufficient.